Brunswick Quay, Liverpool

Proposed Residential Development

Phase 1 Geo-Environmental Investigation

For: Maro Developments Ltd.

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APPENDICES

1.0 INTRODUCTION

This Phase 1 geo-environmental ground investigation and report has been prepared at the request of Mr Chris Stroud of Maro Developments Ltd.

Instructions to proceed were received in February 2018. Desk study work was undertaken between November 2016 and April 2018.

This Phase 1 Geo-environmental Investigation Report is to be used for submission to the Local Authority as part of the planning application as it is the Client's intention to develop the site into a high-rise, predominantly residential development with limited retail use and associated highways, car parking and areas of soft landscaping.

The proposed development plan is contained in Appendix 8. Please note that this is not the finalised development plan and is therefore subject to change.

2.0 BRIEF

The brief was to carry out a Phase 1 geo-environmental investigation for the site at Brunswick Quay, Liverpool based upon the proposed development outlined in Section 1.0. The site area is shown on the site plans contained in Appendix 1.

The investigation was to include the following:

a) Assess the probable ground conditions and contaminated land conditions on and below the site on the basis of existing and detailed historic on-site and relevant off-site activities.

b) Identify probable contaminants / sources of contamination that may be present at the site using current contaminated land guidance and develop a conceptual site model for potential human health and controlled waters receptors.

c) Undertake a Preliminary Risk Assessment – which will determine the requirement for further environmental (contaminated land) investigation and assessment.

d) Design based on the anticipated ground conditions appropriate geotechnical site investigation works and discuss potential development issues i.e. sub-surface features – obstructions, compressible ground, faulting, mineral extraction, mining and land instability.

A summary of the information / data sources is detailed in Section 5.2.

A detailed report was to be provided to summarise findings and to provide recommendations.

3.0 LIMITATIONS OF INVESTIGATION WORK AND REPORT

Desk Study References

For the work, reliance has been placed on publicly available data obtained from the sources identified. The information is not necessarily exhaustive and further information relevant to the site may be available from other sources. When using the information, it has been assumed that it is correct. No attempt has been made to verify this information. New information, revised practices or changes in legislation may necessitate the re-interpretation of the report, in whole or in part.

The desk study has been produced using historical Ordnance Survey maps and environmental maps available at the time the report has been produced. The environmental information used was the current information available at the time of writing but there is no absolute guarantee of accuracy.

Historical Ordnance Survey maps do not provide a comprehensive description of a site history. They provide details of the site from a date prior to the publication of the map (i.e. a snapshot in time). The period between map editions can be substantial (i.e. several decades). Not all map series are available for every date range in many areas of the UK and therefore there will be gaps in this mapped record for some sites. Potentially contaminative land uses could have been present and removed during such periods and may therefore not form a part of this particular record. In addition, there will be potentially contaminative land uses which are not identified on the map records such as small scale storage / use of hazardous materials, illegal / unlicensed waste disposal activities etc.

Different map series identify different features utilising different symbols which can result in features that remain on site being removed from maps. Some features are also not mapped for security reasons i.e. airfields and other military installations. These areas are mostly shown as blank areas on historical maps.

Site Walkover

During the site walkover reasonable effort has been made to obtain an overview of the site conditions. However, during the site walkover no attempt has been made to enter areas of the site that are unsafe or present a risk to health and safety, are locked, barricaded, overgrown, or the location of the area has not been made known or accessible.

Exploratory Holes

Where the spacing of exploratory holes for future intrusive investigation work has been presented as part of this report, the spacing has been determined to provide a reasonable indication of the general ground conditions and extent of land / groundwater contamination on the site but the number has ultimately been limited by commercial constraints. The ground conditions at the proposed exploratory holes are no absolute guarantee of the ground conditions between such locations. Due allowance should be made for the possibility of variation in conditions between exploratory hole locations when preparing any assessments of the final foundation and land / groundwater remediation proposals.

Extent of Contamination Studies

This report is strictly limited to the nature of contamination contained within the ground and groundwater at the site. The report does not cover environmental aspects such as air or noise pollution and ground vibrations and the like. In addition, ecological matters relating to wildlife, flora and fauna have not been investigated as part of this report. In particular, the site has not been inspected for the presence or otherwise of invasive species e.g. Japanese Knotweed. It is recommended that the Client appoints a specialist in this subject to carry out a detailed inspection / survey of the site if its presence is suspected. Where mention has been made to the identification of asbestos or asbestos-containing materials this is for indicative purposes only and do not constitute or replace full and proper surveys. If an Unexploded Ordnance (UXO) report has been obtained within the report, it has been

so on the basis of Health and Safety concerns and no assessment has been made other than transcribing the recommendations of the sub-contractor contained within the report. In terms of a potential contaminative source, unless ordnance has been manufactured / stored on site, UXOs will only be determined as a contaminative source following a positive identification on site.

When investigating, or developing, potentially contaminated land it is important to recognise that sub-surface conditions may vary spatially and also with time. The absence of certain ground, ground gas, and contamination or groundwater conditions at the positions tested is not a guarantee that such conditions do not exist anywhere across the site. Due to the presence of existing buildings and structures access could not be obtained to all areas. Additional contamination may be identified following the removal of the buildings or hardstanding.

Site sensitivity assessments have been made based on available information at the time of writing and are ultimately for the decision of the regulatory authorities.

The conclusions and recommendations sections of the report provide an overview and guidance only and should not be specifically relied upon without considering the context of the report in full. The conclusions resulting from this study are not necessarily indicative of future conditions or operating practices at or adjacent to the site.

Flooding

Flooding in this report is defined as flooding caused by the sea, ditches, rivers, streams, ponds, lakes, reservoirs and the like. It does not extend to flooding caused by surcharged piped drainage systems and investigations into flooding of this nature are excluded from this report.

4.0 THIRD PARTIES

This report has been prepared for the sole use of Maro Developments Ltd. It must not be copied or passed onto any third party or used for any purpose other than which it was prepared without the permission of the author. This report is copyright.

The digital images obtained from the Maritime Archives used in the report are supplied on the understanding that they will only be used in the report and alternative use would require permission from Peel Ports Group & Maritime Archives & Library, Merseyside Maritime Museum.

5.0 SCOPE OF INVESTIGATION WORK

5.1 Walkover Survey

The site was visited on 2nd November 2016 and 20th March 2018, both during dry weather conditions and the objectives of the site walkover were, where applicable :

- to identify and assess visual and olfactory evidence of contamination e.g. staining of concrete / soils, odours, presence of gas protection measures etc;
- to identify locations of potential sources of contamination and assess their conditions i.e. tank location, presence / condition of secondary containment / bunds, location of fill points, process areas;
- to identify surrounding land uses and any potentially contaminating activities;
- to identify / verify the presence of potential receptors (on- and off-site) which may be affected by identified sources;
- to obtain information on activities / procedures and standards of housekeeping etc;
- to assess site access and potential investigation locations and constraints; and
- to assess any visual subsurface geotechnical features / anomalies e.g. foundations, made ground, subsidence etc.

Photographs were taken of the site during the walkover survey and these photographs together with a plan indicating the location and direction of the photographs are contained in Appendix 2.

5.2 Documentation

The following documents were obtained and examined during the desk study :

a) An aerial photograph of the site dated 21st April 2016. The photograph is contained within the Groundsure Enviro-Insight report in Appendix 4.

b) An OS Vector Map dated 2016, contained in Appendix 1.

c) Historical Ordnance Survey maps as follows:

Date of Publication	Scale
1938*	No scale
1847	1:1,056
1848	1:1,056
1850-1851	1:10,560
1890	1:10,560
1893	1:2,500
1897-1899	1:10,560
1906	1:10,560
1908	1:2,500
1908-1909	1:10,560
1911-1912	1:2,500
1924-1928	1:10,560
1925-1928	1:10,560
1927	1:2,500
1936-1938	1:10,560
1938	1:10,560
1952	1:1,250
1953	1:1,250
1952-1953	1:2,500
1954-1956	1:10,560
1966-1967	1:10,560
1968	1:2,500
1970	1:2,500
1974-1976	1:1,250
1978-1982	1:10,000
1987	1:1,250
1989	1:10,000
1987-1991	1:10,000
1990	1:1,250
1988-1993	1:1,250
1993	1:1,250
2002	1:10,000
2010	1:10,000
2014	1:10,000

*Obtained from https://www.gracesguide.co.uk/File:Im1838OsbGuide-Liverpool.jpg [ONLINE] (last accessed 16.03.18).

These maps are contained in Appendix 3.

d) Historic Fire Insurance Plans, dated 1890, obtained from Groundsure. These plans are contained in Appendix 3.

e) Enviro-Insight (environmental) and Geo-Insight (geological) reports obtained from Groundsure, an environmental database company, which provides a list of recorded past and present activities at or adjacent to the site which could have an impact on the levels of contamination in the soils and groundwater at the site. The reports are contained in Appendices 4 and 5, respectively.

f) Environmental maps, all dated 2018 obtained through Groundsure as follows:

- Historical Land Use map;
- Environmental Permits, Incidents and Registers map;
- Landfill and other Waste Sites map;
- Current Land Use map;
- Hydrogeology and Hydrology maps;
- Environment Agency / Natural Resources Wales flood maps;
- Designated Environmentally Sensitive Sites map;
- Geological maps;
- Ground Workings map;
- Mining, Extraction & Natural Cavities map;
- Natural Ground Subsidence maps;
- Borehole Records map;
- Railways and Tunnels map.

These maps are contained within the Groundsure reports in Appendices 4 and 5.

g) 4 No. BGS borehole logs were also obtained (reference: SJ38NW966, SJ38NW28, SJ38NW969 and SJ38NW999). A copy of the borehole logs are contained in Appendix 6.

h) The Indicative Atlas of Radon in England and Wales published by the British Geological and the Health Protection Agency was examined to assess the probable presence or otherwise of radon gas in the ground. Extracts of the relevant maps are contained in Appendix 7.

i) A visit was made to the Liverpool Maritime Archives on 2nd November 2016 to view historic plans of the dockland area to supplement the research. Photographs of archive materials are contained in Appendix 11 courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

j) Previous site investigation works undertaken by Geotechnics Ltd. – Desk Study at Brunswick Quay, Liverpool, Project No. PN030371, April 2004 – was provided by the Client and is referenced in Section 6.6 below.

k) A historical aerial photograph dated circa. 1980 obtained from Britain From Above is contained in Section 6.3 below.

l) Proposed development plans were received from the architect – Plans 16047_Site_Central_SK001 to 16047_Site_Central_SK011. These plans are contained in Appendix 8.

m) A detailed Unexploded Ordnance (UXO) Threat & Risk Assessment report for the site was obtained from Landmark and Alpha 6. This report is contained in Appendix 14.

6.0 FINDINGS

6.1 Description of the Site

The 1.17Ha site is located 2.5km south of Liverpool city centre, on a peninsula between the River Mersey and Brunswick Dock, the southernmost dock in Liverpool's South Docks System. The national Ordnance Survey grid reference for the centre of the site is E334715, N388174 and it is located at approximate post code L3 4BN. The site is bordered to the north and east by Brunswick Dock, to the west by Brunswick 80 Foot Lock and the River Mersey beyond, and to the south by Atlantic Way and further, Brunswick Business Park.

The location is shown on the site location plans in Appendix 1. An aerial photograph of the site is also contained in Appendix 4.

6.2 Walkover Survey

The site is predominantly flat at approximately 8.5m AOD and is bounded by metal fences along the southern and western boundaries. The site can be accessed by a secured metal gate off Atlantic Way to the south. The northern and eastern boundaries are bounded by metal railings and Brunswick Dock beyond.

The site is in current use as parking for new Renault cars. The adjacent 80 Foot Lock is still in use, to permit access for the pleasure craft moored in a floating marina within Brunswick Dock. The surrounding land uses appear to be predominantly residential and commercial.

The western site section is an infilled dock. The eastern site section was historically almost completely covered by a warehouse – see figure 1 below.

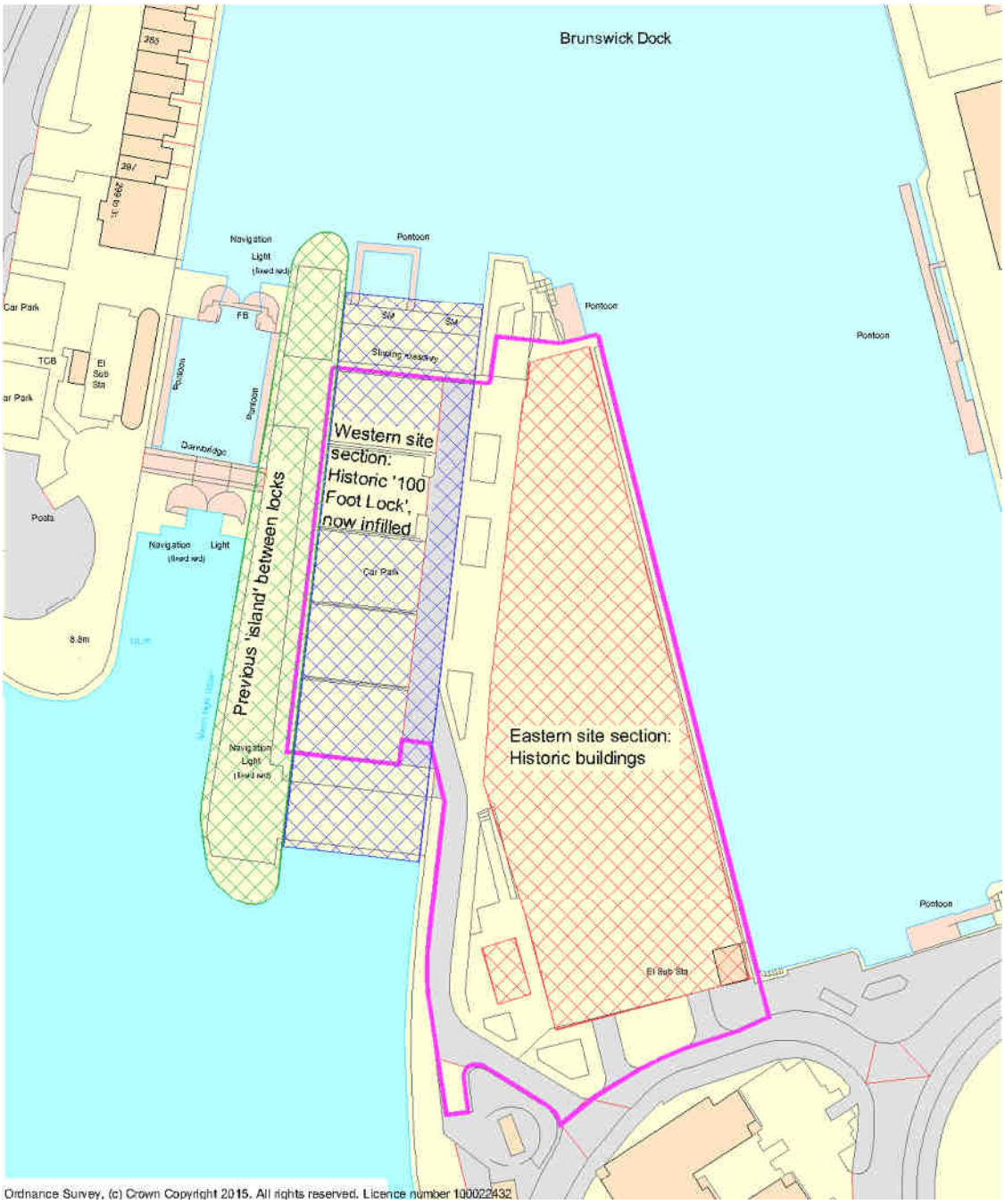

Figure 1 - Site plan showing the eastern and western site sections, Brunswick Dock to the east and north, and the River Mersey to the west and south.

The western site section is characterised by a former tarmacadam car park; the white marker lines, section dividing fences and lamp posts remain. The central part of the site was overgrown at the time of the 2016 walkover with numerous mature trees in areas of suspected former decorative planting, which had been cut to stumps by the

time of the 2018 walkover. The eastern site section is characterised by the suspected former floor slab of the large historic on-site building – this is in parts concrete and in parts cobble setts. The footings of suspected former stanchions can be seen.

The top of the historic 100 Foot Lock walls are evident along the centre of the site and the western boundary (see figure 2 below), both suspected to be constructed of concrete with granite, on the basis of historic plans. Looking at the off-site adjacent 80 Foot Lock (see figure 3 below), the entire lock wall appears to be constructed of concrete with granite, presumably to the dock sill. On this basis, it is likely that on-site buried walls of the 100 Foot Lock are of the same construction.

Figure 2 - Looking east from the centre of the site. The historic 100 Foot Lock wall can be seen in the foreground and associated mooring posts remain in-situ.

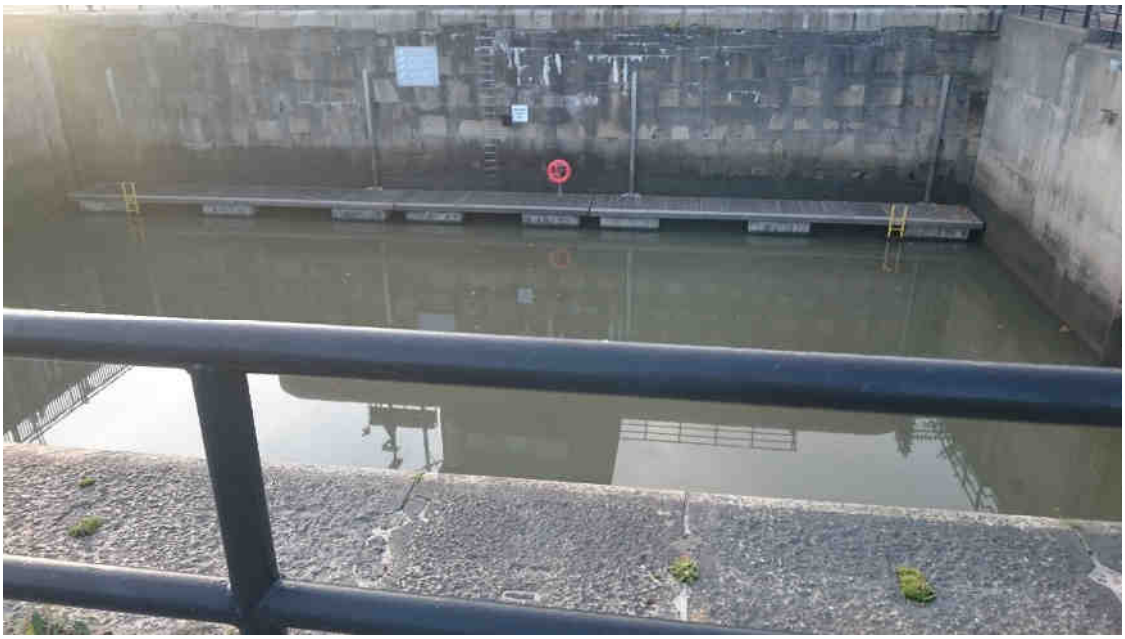

Figure 3 - Brunswick 80 Foot Lock (still in use). The top of the wall can be seen in the foreground, similar to the 100 Foot Lock wall in the centre of the site. The wall construction can be seen on the far side of the lock.

During the walkover survey, no visual or olfactory evidence of contamination was noted. However, an electrical sub-station is present in the south eastern site corner, which appears to have once been part of the large, historic on-site building.

Numerous service grids were noted on the site, although it is unknown if the services they contain are live. A silt pumping pipe was noted to enter the site from the base of a slope on the northern boundary, which possibly runs beneath the site – see Section 6.14

Photographs taken during the walkover survey together with a plan indicating the location and direction of the photographs are contained in Appendix 2.

6.3 Site History

The site development history has been researched by reference to historical maps and street plans, aerial photographs, books and other archive material. The historical maps are included in Appendix 3 to this report.

The site has a complicated and varied history and as such, the off-site and on-site history are summarised together below. The off-site history has been limited to a 100m radius from the site due to the highly changeable nature of the surrounding docklands area and it is considered that the most important historical changes have occurred within 100m of the site. Images of pertinent times in the site's history are also included below.

Dates	On-Site History	Off-Site History
Before 1827	Unknown land use. Docklands have been present in Liverpool since 1715, however, the specific on-site land use is unrecorded before this time.	
1827-1832	**Brunswick Dock** constructed as part of the South Dock System and opened in 1832 principally for importing timber. Possible associated Graving Docks were also constructed.	
1838	By the earliest historical mapping in 1938, a **Graving Dock** is present on site.	The area is predominantly **docklands** and presumably **industrial** buildings. The on-site Graving Dock is one of two adjacent Graving Docks which are connected to Brunswick Dock to the north of the site. Brunswick Dock is connected to the River Mersey by Brunswick Half Tide Dock and other Docks to the north.
1847	By 1847, **numerous buildings** are present partially on site, suspected to be associated with ship building or repair due to their proximity to the Graving Docks.	3 No. **tar boilers**, a **pump** and an **engine house** are present adjacent to the site associated with the Graving Docks. Toxteth Dock has been constructed to the south.
1851	No on-site change	A **railway** has been extended towards the docks and is present 50m east and 10m south of the site.
1890	By 1890, the partially on-site buildings are recorded as '**Ship Building Yards**' and more specifically, '**Ship Builders**', '**Pontoon Repairers**' and '**Mast Maker**'. Each contains various industrial uses, including 'smithy and 'joiners.	Brunswick Dock has been connected to Toxteth Dock by Union Dock 50m to the east. The railway connections in close proximity to the site have been removed. Toxteth Dock has been significantly enlarged towards the south and a Lock is present 50m to the south of the site, connecting Toxteth Dock to the River Mersey. The surrounding docklands are primarily industrial with large warehouses.

1893	No change – see Figure 4 below.	
1894-1906	Sometime around the start of the 20th Century, the ship building yards have been removed and in their place the land has been excavated to create 2 No. locks (**Brunswick Locks**), connecting Brunswick Dock to the River Mersey – the **on-site 100 Foot Lock** (east) and the off-site 80 Foot Lock (west). Associated with these works, Brunswick Dock was also deepened to accommodate larger ships.	
1908	No change – see Figure 5 below.	
1913-1925	Sometime between 1913 and 1925, the Graving Docks have been removed (suspected to have been **infilled**) and in their place a **large warehouse building** has been constructed, covering the majority of the site. 2 No. other small buildings are also present to the south of the site.	Brunswick Dock has been **extended** to the south to subsume Union Dock and connect directly to Toxteth Dock. The lock 50m to the south of the site has been infilled and a **large presumably industrial building** has been extended in its place to abut the site to the south.
1927	No change – see Figure 6 below.	
1953	No on-site change.	The large building abutting the site to the south is recorded as a '**Warehouse**'.
1971	In 1971 the whole South Dock System was abandoned due to a collision at Brunswick Locks, preventing the river gates from closing, allowing **sewage contaminated silt** to enter and causing the entire system to become tidal (see figure 7 below).	
1975	No on-site change.	Brunswick Dock was closed due to the above incident.
1983	No on-site change.	Brunswick Dock regeneration project including the removal of contaminated silt.
1982-1990	Sometime between 1982 and 1990 (suspected 1984), the on-site **100 Foot Lock was infilled** to the level of the surrounding land and a car park was constructed in its place. By 1990, the on-site building is recorded as 'Brunswick Enterprise Centre', housing >50 small businesses.	In 1987, the 80 Foot Lock was reopened for small watercraft with new lock gates.
1990	See Figure 8 below.	
2007-2009	Sometime between 2007 and 2009 the large on-site building was demolished to slab level.	No significant changes.
2009-2018	No on-site change to present. An electrical sub-station is present on site in the south eastern corner, which appears to have been a part of the historic warehouse building, although its age is unknown.	

An aerial photograph of the site as it appears at present is contained in the Groundsure Enviro Insight report in Appendix 4.

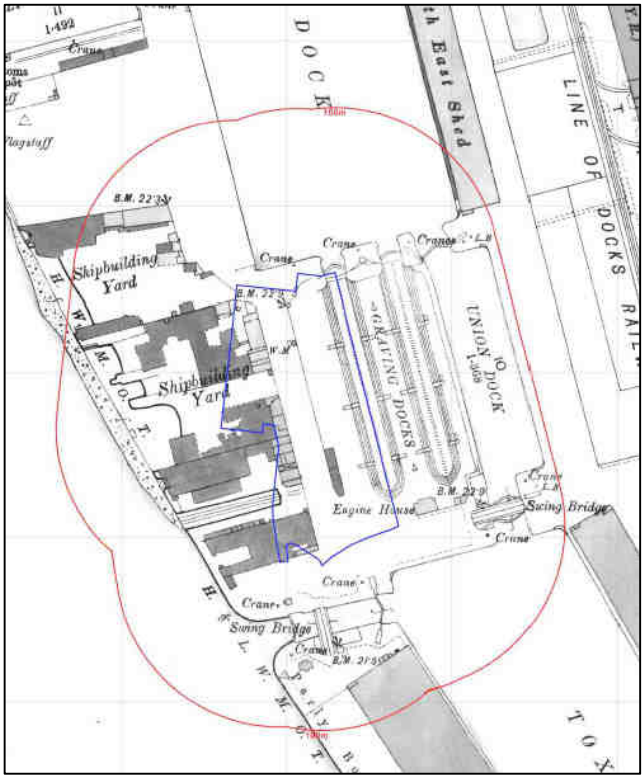

Figure 4 - 1893 OS map of the site. Boundary shown in blue. 100m buffer shown in red.

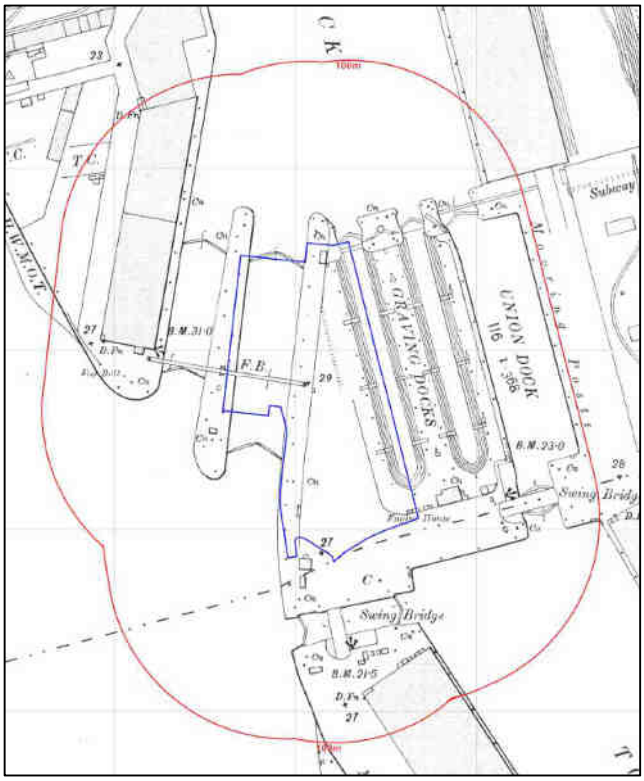

Figure 5 - 1908 OS map of the site. Boundary shown in blue. 100m buffer shown in red.

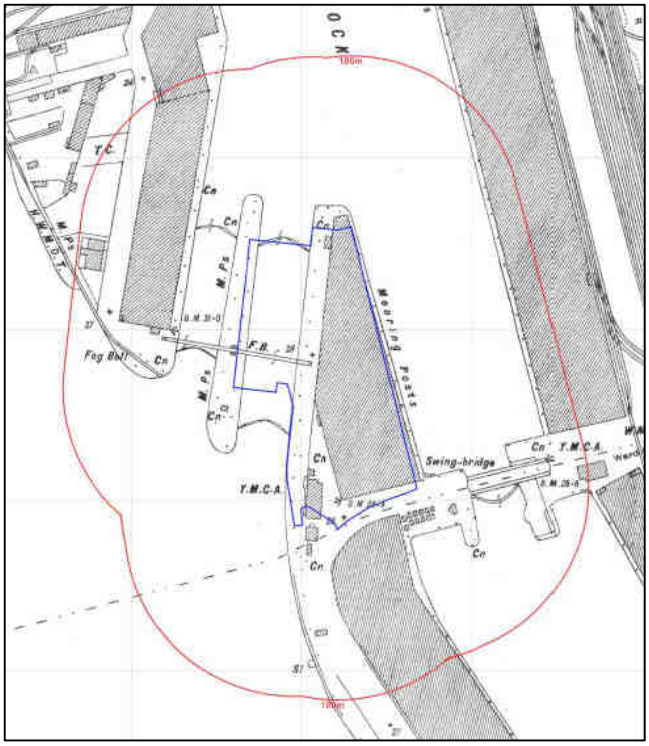

Figure 6 - 1927 OS map of the site. Boundary shown in blue. 100m buffer shown in red.

Figure 7 - C. 1980 aerial image of Brunswick Dock and Locks silted up (obtained from Britain From Above, under license).

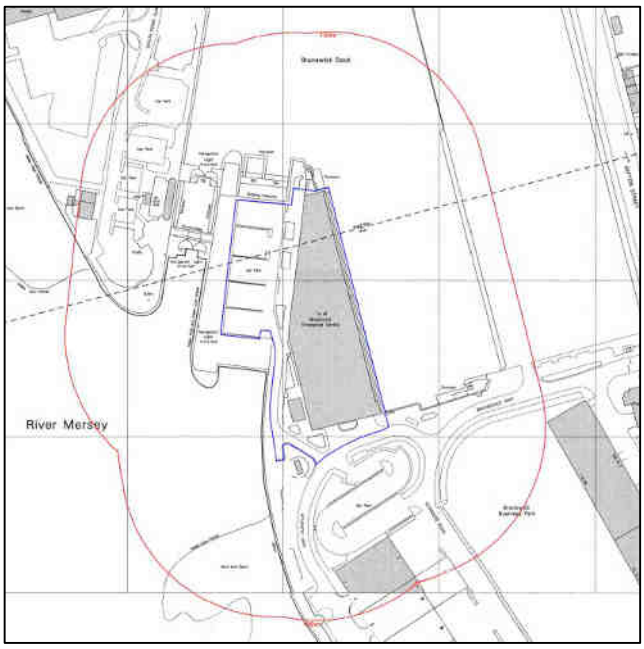

Figure 8 - 1990 OS map of the site. Boundary shown in blue. 100m buffer shown in red.

Beyond the 100m buffer, the site has been surrounded by docklands, warehousing, goods depots, railways and various industrial uses since before the earliest mapping in 1838. The site and surroundings were predominantly a goods import / export and industry area until the late 1980s. Towards the end of the 20th Century, the surrounding area became predominantly commercial and residential, as, at this time, large previously industrial warehouses to the south became 'Brunswick Business Park', Brunswick Dock became partly used as a marina and housing was developed in the area.

Summary of principal historical contaminative sources:

- On and off site dockyards and dockland
- On and off site ship building industry
- Off-site railway
- Infilling of Brunswick 100 Foot Lock and Graving Docks
- Contaminated silt

Archaeology

The historic on-site graving dock is likely to be of archaeological interest due to the important industrial, economic, social and cultural importance of the internationally renowned Liverpool Docklands area.

6.4 Geology

6.4.1 BGS Geological Map

The BGS 1:10,000 Geological Map of the area (reference: SJ38NW) indicates that the majority of the site is underlain by Artificially Modified Ground: Made Ground. No superficial deposits are noted on site. However, given the location of the site, estuarine alluvium may be present in areas. The entire site is underlain, in turn by solid geology of the Chester Formation of the Sherwood Sandstone Group (main bed).

The nearest superficial deposits to the site are Quaternary age Tidal Flat Deposits, 43m south, 97m west, 99m southeast and 119m west of the site, which comprise of sand or clay, silt and sand. The made ground underlying the site is likely to be highly variable in age, depth / thickness, constituents, nature and behaviour. The Chester Formation is Triassic in age, sedimentary in origin and typically consists of bedded, fine to coarse grained, often pebbly (gravelly) sandstone (defined by BGS lexicon).

A fault, named the 'Castle Street Fault', is inferred to outcrop 71m east of the site, trending north to south and downthrowing east. Extracts from the geological map (reference: SJ38NW) are contained in the Groundsure Geo-Insight report in Appendix 5.

6.4.2 BGS Borehole Logs

There was 1 No. available BGS Borehole available on site as follows:

BGS Borehole Reference: SJ38NW966

This BGS borehole was drilled in October 1985, located on-site close to the river wall in the southern site section and was drilled to a depth of 15.05 bgl. Ground conditions were encountered as follows:

- SETTS / CONCRETE to 0.15m bgl (approx. 8.35m AOD), underlain by;

- MADE GROUND comprising ash, stone, brick, slate etc. to 4.00m bgl (approx. 4.50m AOD), underlain by;
- MADE GROUND comprising sand, sandstone pieces etc. to 6.50m bgl (approx. 2.00m AOD), underlain by;
- Very soft / soft, black silty CLAY with 'layers' of sand and silt and organic zones to 8.80m bgl (approx. 0.30m BOD), underlain by;
- Medium dense, grey, organic, silty SAND and sandy SILT to 10.80m bgl (approx. 2.30m BOD), underlain by;
- Stiff to very stiff, grey and brown, sandy CLAY with stone inclusions and grey fissures (softened upper zone) to 13.30m bgl (approx. 4.80m BOD), underlain by;
- Soft to firm dark grey and red SANDSTONE (oxidises to red) to at least 15.05m (approx. 6.55m BOD) at termination.
- No groundwater was recorded in this borehole.

Furthermore, 3 No. BGS borehole logs were obtained from the surrounding area within the same geological setting to that which is present at the site in terms of superficial deposits and underlying solid geology. Consequently, it is anticipated that the underlying stratigraphy will be similar to that which is encountered beneath the site.

<u>BGS Borehole Reference: SJ38NW28</u>

This BGS borehole was drilled in October 1976, located 116m east of the site. The borehole was drilled to a depth of 23.00m bgl (14.475m BOD). Ground conditions were encountered as follows:

- SETTS to 0.20m bgl (8.325m AOD), underlain by;
- CONCRETE to 0.40m bgl (8.125m AOD), underlain by;
- MADE GROUND comprising red sandstone, sand etc. to 5.00m bgl (3.525m AOD), underlain by;
- Soft, brown to black, silty CLAY to 11.60m bgl (3.075m BOD), underlain by;
- Highly to moderately weathered, moderately weak, pinkish brown and light grey, thinly bedded fine / medium SANDSTONE (Bedding generally at shallow

angle. Discontinuities at 14.8 [60º], 16.1 [45º]) to 16.90m bgl (8.375m BOD), underlain by;

- Highly weathered, weak, very thinly and thinly bedded, reddish brown, fine / medium grained SANDSTONE with light grey lenses (Broken core zones at 17.0-17.3m, 18.4m and 18.7m bgl. Bedding generally at shallow angle) to 19.90m bgl (11.375m BOD), underlain by;
- Completely to highly weathered, very weak, reddish brown, very thinly bedded and laminated, fine / medium SANDSTONE with light grey lenses (Bedding generally at shallow angle. Broken core in several parts.) to 23.00m bgl (14.475m BOD) at termination.
- Fresh water entry noted at 15.60m bgl, and rose to 13.10m bgl. Left over night – water level standing at 13.70m bgl.

BGS Borehole Reference: SJ38NW969

This BGS borehole was drilled in December 1985, located 44m west of the site. The borehole was drilled to a depth of 19.70m bgl. Ground conditions were encountered as follows:

- MADE GROUND comprising bricks, concrete, beams, silt and clay to 17.00m bgl, underlain by;
- CONCRETE to 18.25m bgl, underlain by;
- Brown SAND to 19.70m bgl at termination.
- No groundwater was encountered in this borehole.
- Drilling flush lost between 3.00m and 17.00m before casing was inserted.

BGS Borehole Reference: SJ38NW999

This BGS borehole was drilled in November 1984, located 40m east of the site within Brunswick Dock and was drilled on a pontoon over the water and begun from 'Dock Bottom (DB)'. The borehole was drilled to a depth of 11.50m below DB (8.37m BOD). Ground conditions were encountered as follows:

- Very soft, black, silty CLAY (odorous) to 6.35m below DB (3.22m BOD), becoming slightly sandy from 3.70m below DB, underlain by;

- Very soft to soft, dark grey, slightly sandy, to sandy, very silty CLAY with laminations of brown, fine to medium sand (not always present), to 8.90m below DB (5.77m BOD), underlain by;
- Soft, brown, very clayey, slightly sandy SILT with many (approx. 40% of material) pockets of very soft, black, very silty CLAY, to 10.00m below DB (6.87m BOD), underlain by;
- Soft to firm, black / brown mottled, slightly sandy, very silty CLAY with possibly occasional sand laminations, to 11.00m below DB (7.87m BOD), underlain by;
- Red, fine to medium grained, strong, fresh SANDSTONE to 11.50m below DB (8.37m BOD) at termination.
- No groundwater was recorded in this borehole.

6.4.3 Geohazards

Data Type	Details
Ground Stability Data	➢ The Potential for Landslide Ground Stability Hazards at the site is regarded as very low. ➢ The Potential for Running Sand Ground Stability Hazards at the site is regarded as very low to negligible. ➢ The Potential for Shrinking or Swelling Clay Ground Stability Hazards at the site is regarded as negligible. ➢ The Potential for Collapsible Ground Stability Hazards at the site is regarded as very low. ➢ The Potential for Compressible Ground Stability Hazards at the site is regarded as very low to negligible. ➢ The Potential for Dissolution Ground Stability Hazards at the site is regarded as negligible.

6.4.4 BGS Estimated Soil Chemistry

Although there are no recorded superficial deposits on site, the BGS have estimated that the nearby river terrace and alluvium deposits are anticipated to naturally comprise of the following determinands:

- Arsenic <15mg/kg
- Cadmium <1.8mg/kg
- Chromium 60 – 90mg/kg
- Lead <100mg/kg
- Nickel 15 – 30mg/kg

6.5 Mining

No records of historical or present coal or non-coal mining are located within 1km of the site. However, 4 No. sandstone quarries are recorded between 615m and 936m east of the site and between 777m and 853m south east of the site, all of which have 'ceased' status.

6.6 Previous Site Investigations

6.6.1 Geotechnics Desk Study Report

A previous Desk Study report was undertaken by Geotechnics Ltd. in April 2004 was provided by the Client and relates to the site prior to demolition of the historic on site Brunswick Enterprise Centre.

Pertinent information obtained from the Geotechnics Ltd. Desk Study Report is as follows:

- Aside from the main Brunswick Enterprise Centre building, the other recorded historic on-site building was a small 2-storey office block known as 'E block', which was topographically, approximately 1m lower than the surrounding walkways.
- Geotechnics state that towards the northern site section: 'the concrete dock wall is cracked. The crack has had a glass side cemented over it to indicate any recent outward movement. The crack is rust coloured, suggesting possible corrosion of steel reinforcement within it'.

BGS Boreholes Obtained by Geotechnics

BGS confidential boreholes were obtained: SJ38NW217 and SJ38NW218 and were named, respectively Borehole 1 and Borehole 2. These boreholes were drilled between February to March 1984, during infilling of the 100 Foot Lock.

The ground conditions encountered are as follows (OD=5.95m):

Borehole 1

- Granular MADE GROUND comprising medium dense, silty, sandy, gravel of brick debris, sandstone and timber, with hydrocarbon contamination and organic debris, with possible cobble to boulder sized inclusions, to 4.05m BOD, underlain by;
- Medium dense, black, organic, silty SAND with hydrocarbon contamination to 5.55m BOD, underlain by;
- Soft to firm, laminated, dark grey and brown, organic CLAY / SILT to 8.25m BOD, underlain by;
- CONCRETE lock sill to 9.35m BOD (1.10m thick), underlain by;
- Red and black, silty SAND (possible completely weathered sandstone) to 9.85m BOD, underlain by;
- SANDSTONE bedrock comprising red, completely weathered, uncemented, becoming weakly cemented, silty, fine grained sandstone to 11.15m BOD at termination.
- Medium inflow of groundwater encountered at 1.45m AOD.

Borehole 2

- Drilled overwater from pontoons.
- 10.00m thickness of varied ALLUVIAL DEPOSITS comprising generally loose, dark grey-brown, very silty SAND with layers of very soft to soft, organic clay and silt to 7.25m BOD, underlain by;
- CONCRETE (sill of 100 Foot Lock) to 7.65m BOD (0.40m thick), underlain by;
- TIMBER to 9.05m BOD, underlain by;
- SANDSTONE bedrock comprising red, completely weathered, uncemented, becoming weakly cemented, silty, fine grained sandstone to 10.05m BOD at termination.
- No groundwater was recorded.

6.6.2 Geotechnics Ground Investigation Report

A previous Ground Investigation report was also undertaken by Geotechnics Ltd. in April 2004 and was provided by the Client. This also relates to the site prior to demolition of the historic on site Brunswick Enterprise Centre.

Pertinent information obtained from the Geotechnics Ltd. Ground Investigation Report is as follows:

- 5 No. 150mm diameter cable percussion boreholes were sunk to depths between 15.70m and 17.05m bgl. These were continued with open hole rotary drilling and rotary core drilling to depths between 17.40m and 41.00m bgl.
- Rock coring was commenced at between 15.70m and 19.00m bgl.

Ground conditions were encountered as follows:

Boreholes in area of infilled 100 Foot Lock

- TARMACADAM underlain by limestone SUB-BASE (car park) to 0.60m bgl, underlain by;
- Coarse, granular MADE GROUND comprising 'demolition rubble' to 11.50m bgl, underlain by;
- ALLUVIUM comprising firm, black, organic, silty CLAY with bands of silt and sand to 17.00m bgl, underlain by;
- CONCRETE dock sill to 18.10m bgl, underlain by;
- SANDSTONE bedrock to at least 41.00m bgl at termination.

BH3 in area of former warehouse building

- CONCRETE footpath to an unknown depth, underlain by;
- Granular MADE GROUND containing a further 2 No. concrete layers (the maximum thickness of which was between 2.50m and 3.70m depth) to 4.80m bgl, underlain by;
- Cohesive MADE GROUND comprising firm, reddish brown, slightly gravelly, sandy CLAY with sandstone and brick fragments to 12.50m bgl, underlain by;

- Reddish brown mottled black, silty SAND to 13.20m bgl, underlain by;
- 'Apparently natural GLACIAL TILL' to 13.50m bgl, underlain by;
- SANDSTONE bedrock to at least 40.70m bgl at termination.

BH4 in area of former warehouse building

- Pavement construction materials and CONCRETE to 0.60m bgl, underlain by;
- Granular MADE GROUND fill comprising loose to medium dense, reddish brown sand and gravel of sandstone, to 8.00m bgl, underlain by;
- Varied ALLUVIAL sequence comprising organic silt, sand and gravel deposits to 15.70m bgl, underlain by;
- SANDSTONE bedrock to at least 39.00m bgl at termination.

Using the above information, the sandstone bedrock falls into Rock Mass Class IV, described as 'poor rock', with a typical lower bound friction angle for the rock mass of 30^{o}.

Groundwater

- Groundwater was encountered in the area of the infilled lock at between 3.50m and 3.90m bgl, rising to between 3.40m and 3.75m bgl after 20 minutes.
- Groundwater was encountered in the area of the former warehouse building at between 7.00m and 8.00m bgl, rising to between 6.90m and 7.00m bgl after 20 minutes.
- Therefore, the groundwater in the infilled lock is considered to be in hydraulic continuity with Brunswick Dock as the water was encountered at roughly the same level.
- However, the water level was significantly different within the rest of the site, which causes Geotechnics Ltd. to presume that the Brunswick Dock walls are impermeable. They suggest that water levels in this location may instead be in hydraulic continuity with the adjacent river water and may therefore have a **tidal variation**.

Contamination Testing

- Chemical testing of site soils was undertaken and 'generally', GACs were found not to be exceeding the criteria for the 'residential without plant uptake' end use scenario, except total sulphur, total sulphate and sulphide. Elevated levels of phytotoxic determinands were encountered.
- Groundwater was found to contain concentrations of selenium, phenols, ammoniacal nitrogen, chloride and sulphate in exceedance of allowable Water Supply Regulations (1989) concentrations.

Gas Monitoring

- Gas monitoring of on-site wells was undertaken and the results are as follows:
  - Widespread methane concentrations = 0.1%v/v.
  - BH3 max methane concentration = 88.6%v/v.
  - BH3 max flow rate = >99l/hr.
  - Carbon dioxide not encountered above detection limits.
  - BH3 max oxygen concentration = 5.3%v/v.
  - A vent was fitted to BH3 to vent the methane to atmosphere.
- The gas in BH3 was considered to arise from organic rich alluvium deposits in isolated pockets and Geotechnics Ltd. consider it to be finite and therefore releasable through venting.

Concrete Classification

The potential for chemical attack on buried concrete was tested. Geotechnics have found that:

- Site soils have a Characteristic Value for water soluble sulphate within Design Sulphate Class DS-2 of BRE Special Digest 1 (2001).
- The ACEC class is AC-2.

Further detailed information including specific rock characteristics can be found in the complete Geotechnics Ltd. reports in Appendix 13.

6.7 Hydrology and Hydrogeology

Environmental data relevant to the site and its immediately surrounding area has been obtained from sources available in the public domain. In addition, an environmental report was obtained from Groundsure, a commercial supplier of environmental data. The Groundsure Enviro Insight report and associated maps that have been inspected are presented in Appendices 4 and 5, and the principal observations in relation to waters and flooding can be summarised as follows:

Data Type	Details
Flooding	➢ Parts of the southern and western site sections lie within **Flood Zone 3**.
Surface Water Features	➢ There are no recorded surface water features located on-site. ➢ There are 2 No. surface water features in close proximity to the site: The nearest is Brunswick Dock, which abuts the site to the north and east and is mainly used for pleasure craft. The River Mersey, a Tidal and Primary River, is located 18m west of the site.
Surface Water Abstractions	➢ There are no recorded surface water abstraction licenses located on-site or within 2km of the site.
Groundwater Abstractions	➢ There are 4 No. groundwater abstraction points within 2km, the nearest located 546m southeast of the site. These abstraction points relate to a quarry company, a brewery, a 'City Quay Management' company and a construction / civil engineering company.
Nitrate Vulnerable Zones	➢ There are no nitrate vulnerable zones located on-site or within 2km of the site.
Superficial Aquifer	➢ The site is not underlain by superficial deposits, according to geological mapping. ➢ The nearest superficial deposits (99m southeast) are designated as unproductive strata.
Bedrock Aquifer	➢ The site is underlain by bedrock designated as a **Principal Aquifer**.
Source Protection Zones	➢ The site does not lie within or within 500m of a Source Protection Zone.
Licensed Discharge Consents	➢ There is 1 No. licensed discharge consent located on site relating to the discharge of surface water to the Mersey Estuary. ➢ There are 8 No. licensed discharge consents located within 500m of the site relating to the discharge of treated or unspecified sewage to the River Mersey.
Pollution Incidents to Controlled Waters	➢ There are no recorded pollution incidents to controlled waters located on-site or within 500m of the site.

For further details please see the Groundsure Enviro Insight report attached in Appendix 4.

6.8 Hazardous Installations, Landfill and Waste

The following information relating to hazardous installations, landfill and waste obtained from the Groundsure Enviro Insight report, published information and the walkover survey can be summarised as follows:

Data Type	Details
Environment Agency Recorded Landfill Sites	➢ There are no active Environment Agency landfill sites within 1km of the site. ➢ There is 1 No. Environment Agency recorded historic landfill site **located on site** which pertains to the infilled 100 Foot Lock. The waste type is recorded as inert and the infilling dates are unknown, but suspected to be around 1984. ➢ There are a further 6 No Environment Agency recorded historic landfill sites located within 1km of the site, containing industrial or inert waste types. The nearest is located 12m to the south, pertaining to the infilled Toxteth Dock.
BGS Recorded Landfill Sites	➢ There are no BGS recorded landfill sites located on-site or within 1.5km of the site.
Local Authority Recorded Landfill Sites	➢ There are no Local Authority recorded landfill sites located on-site or within 1.5km of the site.
Part A(2) and Part B Activities and Enforcements	➢ There are no Part A(2) and Part B Activities and Enforcements located on site. ➢ There are 5 No. Part A(2) and Part B Activities and Enforcements recorded within 500m of the site, relating to a vehicle refinisher, dry cleaning, unloading fuel into storage at 2 No. PFS and surface treatment of metals. None of these activities resulted in enforcement.
Registered Radioactive Substances	➢ There are no Registered Radioactive Substances recorded on-site or within 500m of the site.
Registered Waste Treatment, Transfer or Disposal Sites	➢ There are no registered waste treatment, transfer or disposal sites located on-site ➢ There are 3 No. registered waste treatment, transfer or disposal sites located within 500m of the site, all scrap yards, the nearest of which is 249m east of the site.
Industrial Land Use	➢ An **electrical sub-station** is located on site. ➢ There are a further 6 No. electrical sub-stations located within 250m of the site, the nearest of which is 37m south of the site. ➢ There are a further 10 No. industrial land uses located within 250m of the site, the nearest of which is 113m east, pertaining to the armed services.

6.9 Radon

The Indicative Atlas of Radon in England and Wales produced by the Health Protection Agency and British Geological Survey indicates that the site lies within a lower probability area as less than 1% of homes are above the action level. Consequently, BR211 (2015) indicates that no radon protection measures are necessary in the construction of new dwellings or extensions.

Map 13 of the Indicative Atlas of Radon in England and Wales and Map 13 of BR211 (2015) are contained within Appendix 7.

6.10 Microbiological Hazard / Anthrax

A New Scientist magazine article from 20th October 1983 was obtained, entitled 'Anthrax Pushes Up the Liverpool Daisies'. This article states that 'anthrax spores may lurk just three metres below the surface of Herculaneum Dock, which is now filled with sand'. Herculaneum Dock was historically located approximately 1.14km south of the site. This is due to the historic importation of wool in the north docks and the demolition materials of these north dock buildings being filled into Herculaneum Dock in 1978.

The article goes on to state that 'some 4.5 million tonnes of silt that may be contaminated has since been pumped out of Herculaneum Dock […] (and) now sits in the nearby Coburg and **Brunswick Docks**'.

Starting in 1983, as noted in the site history above, Brunswick Dock was part of a regeneration project* including the construction of a marina, infilling of the 100 Foot Lock and installation of new gates on the 80 Foot Lock. At this time, Brunswick Dock was also reportedly cleared of contaminated silt. However, this process may not have been perfect and there is a residual risk that some Anthrax (*Bacillus anthracis*) spores may remain, especially at the base of the infilled 100 Foot Lock.

*Jones, R. (2004) *The Albert Dock, Liverpool*. RJ Associates Ltd.

6.11 UXO

A Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment Report has been obtained for the site from Landmark and Alpha 6.

The report states that the site is at threat from unexploded WWII German high explosive (HE) bombs. And that all types of aggressive intrusive engineering activities, including site investigation and piling, may generate a significant risk pathway.

Alpha 6 designate the site as **high risk**.

Recommendations to reduce the risk to ALARP are:

1. Provide an operational UXO Emergency Response Plan
2. Provide UXO Safety & Awareness Briefings for all personnel undertaking intrusive works on the site
3. Utilise a non-intrusive UXO survey and/or EOD banksman support where open intrusive works into previously undisturbed ground are proposed
4. Utilise an intrusive UXO survey where blind intrusive works (such as boreholes and piling) into previously undisturbed ground are proposed, such as down-hole magnetometer or MagCone techniques.

The full report is contained in Appendix 14.

6.12 Maritime Archive Visit

It is anticipated that the site will contain many subsurface obstructions due to its varied development history and the high likelihood that much of the past construction materials will have been left in situ.

A visit was made on the Liverpool Maritime Archives on 2nd November 2016 to view historic engineering plans. Photographs were taken of these plans and are included with descriptions in Appendix 11, courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum). It is recommended to view Appendix 11 with the following table.

The findings are as follows:

Resource No. (see Appendix 11)	Resource	Information	Appendix
1	Plan and sections through air shaft, gate opening machine pit, lock gates and gate closing machine pit.	Plan shows: • Plan view of east wall of 100 Foot Lock and 4 No. sections through wall. • All sections show extents of concrete (present in significant thickness), location of shallow pipe trench and deep culvert. • Section AA shows section through air shaft showing depth and connection to underground culvert. • Section BB shows section through gate opening machine pit (2.82m depth x 1.98m width). • Section CC shows section through lock gate and top of wall overhang. Also shows 'old raily [railway] metal' at approx. 1.5m centres between ground level and 0.91m depth. • Section DD shows section through gate closing machine pit (2.82m depth x 1.98m width).	Appendix 11 and Appendix 9.
2	'Plan Showing General Arrangement of Sluices'	Plan view shows: • Location of culvert through centre of island between 80 Foot and 100 Foot Locks. Dimensions = 3.05m width x 3.66m depth, at 12.95m bgl. • Location of culvert through eastern wall of 100 Foot Lock. Dimensions = 3.05m width x 3.96m depth, at 12.65m bgl. • Connections of sluices exiting to River Mersey or Brunswick Dock. Dimensions = 1.82m x 1.82m.	Plan view included on Geo-Environmental Features Plan in Appendix 9.
3	'Plan And Section Of Hydraulic, Gas & Water Culvert'	Plan view shows: • Location of a **1.52m diameter cast iron culvert passing from west side of 80 Foot Lock to east side of 100 Foot Lock** • 3 No. connections from culvert to surface: 1 in the western wall of the 80 Foot Lock, 1 in the central island and 1 in the east wall of the 100 Foot Lock. Cross section shows: • Depths of culvert beneath locks and approximate locations of connections to surface from lock walls where they intersect with the shallow pipe trench.	Plan view included on Geo-Environmental Features Plan in Appendix 9. Cross section included in Indicative Cross Section Through Brunswick Quay in Appendix 10.
4	'Deepening Foreshore Outside Brunswick River Entrances (Work O): Plan Showing Soundings Taken'	Plan view shows: • Dip of rock in a channel towards the 80ft and 100 Foot Locks. • Point data for rock depths. • Old Dock Sill (ODS) is used as a datum.	Plan view included on Geo-Environmental Features Plan in Appendix 9.
5	Section B through wall to the south of historic Toxteth Lock	Cross section sketch shows: • Toxteth Lock was located approximately 21m south of the site. • River Wall to south of Toxteth Lock.	Cross section sketch and context plan are

		• The (presumably concrete) wall widens towards the top. Behind it is 'rock rubble filling' almost to old dock sill (ODS = 10.06m bgl). This is underlain by 'silt', underlain by a relatively thin layer of 'clay', underlain by 'rock' at roughly 14.6m bgl.	included in Appendix 11.
6	'Brunswick New River Entrances' plan	Cross section shows: • 100 Foot and 80 Foot Locks. • Old Dock Sill (ODS = 10.06m bgl) is used as a datum. • Many depths and measurements and locations of deep culverts and shallow pipe trenches. • Dock walls appear to be constructed of concrete (orange on drawing) which widens towards the base. • The space between the walls appears to be filled with gravel (brown mottling on drawing). • The base of the locks appear to be covered in a layer of concrete approximately 1m thick, underlain by possibly more concrete (1.22m thick), underlain by rock (red mottling on drawing). Other cross sections show: • Elevation of island between locks looking east of the 80 Foot Lock and elevation of wall looking west of 80 Foot Lock. • Wall construction, locations of chain pipes, gate mechanisms, the hydraulic, gas & water culvert and other unlabelled features. • A note on the drawing states that the wall is 'faced with 6 to 1 concrete with granite'.	Original cross sections included in Appendix 11 and Indicative Cross Section Through Brunswick Quay in Appendix 10.
7	'Foundations for Outer gate and Caisson Sill for 80'0'' Entrance' plan and cross sections	Plan view shows: • 80 Foot Lock and half of 100 Foot Lock • Rock levels at end of cast iron culvert where it crosses 80 Foot Lock. • Underwater section which extends into the river to the south of the locks and the location of the timber piles which secure it. • Section AA shows cross sectional view across 80 Foot Lock and apparent rock cut beneath it to include the gas and water main, with lock construction materials including gravel and '8 to 1 concrete with plenty of burrs'. • Section BB shows a cross section through the gate sill with rock level and base construction. • Section CC shows a cross section through the caisson sill with rock level and base construction. • Section DD shows a cross section through the river-facing end of the island between the locks. This shows the concrete extending past the end of the island beneath the water, which is secured to rock with 0.30m x 0.30m timber piles. Also shows culver outlet and wall construction including '8 to 1 concrete with plenty of burrs'.	Plan and sections included in Appendix 11 and Section AA has been added to a larger cross sectional drawing (Indicative Cross Section Through Brunswick Quay) included in Appendix 10.
8	'Plan, Elevation & Section of Intended River Entrances Into Brunswick Dock'	Note: *this plan is an **intended** layout and as such, the final construction detail may have deviated from this.* Plan shows: • Brunswick Locks and Brunswick No. 2 Graving Dock. • Section AB shows the eastern wall of the 100 Foot Lock and river wall, along to Toxteth Lock to the south. • Indented layouts and the mean tide level is given.	Plan and sections included in Appendix 11.

		• Section CD shows a cross section of the Brunswick Locks entrances and Toxteth Lock and the approximate rock level (red shading).	
9	Plan of land to the west of Brunswick Dock	Plan shows: • Northern part of the site before the Brunswick Locks were constructed. • Brunswick Half Tide Dock • The industrial 'shed' present to the immediate north of the site.	Plan included in Appendix 11.
10	Plan of Brunswick Dock	Plan shows: • The site post-construction of the Brunswick Locks. • Brunswick no. 2 Graving Dock is present on site. • Brunswick Dock is surrounded by industrial warehouses to the east and west. • Union dock connects Brunswick Dock to Toxteth Dock to the South. • Brunswick Dock is connected directly to Coburg Dock to the north.	Plan included in Appendix 11.
11	'Plan for Setting Out Works'	Plan shows: • Overlay of planned Brunswick Locks over land and previous buildings in place of which they were to be built.	Plan included in Appendix 11.
12	Possible foundation plan for base of 100 Foot Lock	A long plan shows the 100 Foot Lock in detail: • Many small, evenly spaced dots are present along its length – these are conjectured to be the locations of timber piled foundations.	Plan included in Appendix 11.
13	'Brunswick River Entrances: Island' plan and cross sections	Cross sections show: • West side and east side walls of the island between the Brunswick Locks. Plan view shows island construction: • The river-facing end of the island has a significant thickness of concrete beneath it, presumably to act as a breaker for the head of river water. • The concrete is either 10 to 1 or 8 to 1 and various sub surface features are founded upon it.	Plan included in Appendix 11.
14	'Brunswick River Entrances Foundation Plan'	Plan view shows: • Depths of foundations of the 100 Foot Lock, its walls, the 80 Foot Lock, its walls and the island between them. • Depths are given in feet below ODS (Old Dock Sill, 10.06m bgl). • Most parts are formed on rock (pink), except the southern-most part of the island and roughly the southern half of the 80 Foot Lock are founded on gravel. • Some parts are labelled with the dates they were constructed.	Plan included in Appendix 11.
15	'Brunswick 100ft River Entrance: Examination of floor of lock March 1926' plan, plan of damage to underside of 100 Foot and 80 Foot Locks and section AB.	Plan shows: • Details of damage to lock floor as reported by divers. • Some of the concrete was reported as damaged and was repaired, indicating that the thickness of the concrete lock floor may be of variable thickness and quality. • Damage to the underside of both locks; this is unlabelled but is possibly water ingress where the locks are not completely watertight (this plan is also shown in section).	Plans and section included in Appendix 11.

16	'Plan to Accompany Invitation to Tender For Hydraulic Machinery'	• Plan details locations of hydraulic machinery. • Sections show hydraulic clough shafts including construction and depth. • Another section through the Brunswick Locks shows the locations and depths of opening and closing chains.	Plan and sections included in Appendix 11.
17	Historic warehouse plans	• Cross section shows dimensions and construction of footings of the large historic warehouse building. • A blueprint cross section though the length of the building shows the height of the building, the roofs and the width of both halves of the building. • A blueprint plan view shows the locations of footings and the distance of the building from the edge of the dock. • Another plan view shows the historic warehouse with dimensions and locations of footings. • A close up plan view shows the locations of drains within the building. • A cross sectional plan shows a view of the subsurface construction beneath the warehouse building, against the dock wall.	Plans and sections included in Appendix 11.
18	'Plan Shewing Arrangement of Hydraulic Pipes'	Plan view shows: • Locations of hydraulic pipes within the deep culvert that passes below both locks and the shallow pipe trenches along the lock walls. • Due to the age of these plans and that the 100 Foot Lock has been infilled, it is anticipated that these pipes are no longer present, however, this cannot be discounted completely. Section AA shows: • A **cross section through the site**. • 100 Foot Lock wall construction. • The site (does not show strata or subsurface features) contains 4 No. 'centre line of column' markers – it is unclear what these pertain to, possibly the historic warehouse, although it was not constructed at the time of drawing of the plan. • Location of the historic 'Brunswick No. 2 Graving Dock' and a small part of the off-site Brunswick No. 1 Graving Dock. The historic ground level at either side of them is shown to be uneven. • The construction of the Brunswick Dock wall (approximately 16m deep) is right through the centre of the Brunswick No. 2 Graving dock (the base of which is at ODS, 9.45m bgl) and appears to be entirely constructed of concrete with a shallow pipe trench running along its length, not noted on any other plans. • The depth to the bottom of the dock is given to be 16m bgl. • A possibly paved area appears to extend past the dock wall, however, it is unclear what this pertains to as the cross section appears to show Brunswick Dock post construction of the extension to the south (due to the placement of the dock wall), therefore the area shown as land is expected to be water.	Plan and sections included in Appendix 11 and Section AA has been added to a larger cross sectional drawing (Indicative Cross Section Through Brunswick Quay) included in Appendix 10.

*All drawings are undated unless noted otherwise. Images reproduced courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

6.13 Anecdotal Evidence

As explained above, a 1.52m diameter cast iron culvert is noted on historical plans to pass beneath both of Brunswick Locks. A meeting with the Liverpool Dock Harbour Manager has revealed that anecdotally, the culvert is unlikely to remain in use for the operation of the 80 Foot Lock as more modern systems have been emplaced. However, it is unlikely to have been removed as part of the infilling works of the 100 Foot Lock due to its depth (approximately 17.7m bgl). Therefore, it is **likely to remain in situ beneath the proposed development**.

A pipe is present entering the north of the site from Brunswick Dock, which is used to pump water to the southern end of the 'island' between the Brunswick Locks to clear silt, preventing blockage of the 80 Foot Lock entrance. The locations of each end of this pipework has been noted above ground, see Plates 34 and 35 of the site walkover photographs in Appendix 2. However, the route this pipe takes is unknown and may pass beneath the site. It is recommended that this is investigated using non-intrusive techniques.

7.0 CONCLUSIONS

7.1 General

The site contained one of the two Brunswick Graving Docks and ship building / repair operations until sometime around the start of the 20th Century, when the buildings were removed and the 100 Foot Lock was constructed on site along with the adjacent 80 Foot Lock. Sometime in the early 1900s, the graving docks were infilled or possibly removed, a new dock wall (now forming the eastern boundary) was constructed as Brunswick Dock was extended to the south adjacent to the site and a large warehouse was constructed over most of the eastern site section. Brunswick Dock ceased to be a commercial dock in the early 1970s. Sometime in the 1980s the 100 Foot Lock was infilled, and a car park constructed in its place – this is noted as an Environment Agency landfill containing 'inert waste'. The on-site warehouse became the 'Brunswick Enterprise Centre' in 1990 and was demolished in the early 2000s.

7.2 Geotechnical and Geology

The anticipated ground conditions in the eastern site section are:

- MADE GROUND comprising concrete / paving footpath construction to an unknown depth, underlain by;
- FILL: [in places] clay with gravel of sandstone to 12.50m bgl or [in places] sand and gravel of sandstone and brick to 8.00m bgl, underlain by;
- [IN PLACES] ALLUVIUM comprising organic sand, silt and gravel to 15.70m bgl, underlain by;
- Weathered SANDSTONE bedrock to at least 40.70m bgl at termination.

The anticipated ground conditions in the western site section are:

- TARMCADAM underlain by limestone SUB-BASE to 0.60m bgl, underlain by;
- MADE GROUND comprising medium dense, silty sandy GRAVEL of brick, sandstone and timber, with cobble to boulder sized inclusions (demolition waste) to 11.50m bgl, underlain by;

- Varied ALLUVIAL DEPOSITS comprising organic silty SAND / silty CLAY to 17.00m bgl, underlain by;
- CONCRETE dock sill (up to 1.10m in thickness), underlain by;
- [IN PLACES] TIMBER (up to 1.40m in thickness), underlain by;
- SANDSTONE to at least 41.00m bgl at termination.

NOTE: These ground conditions are likely to be highly variable. The made ground is likely to be highly variable with numerous types of fill. Numerous historic obstructions are anticipated, possibly including the historic graving docks, and, in places, a significant thickness of concrete is anticipated - see Section 7.9 below for more detailed information.

Sandstone Bedrock

The bedrock level is anticipated to be variable as it is likely to have been excavated in places to accommodate the locks and additional subsurface constructions. There is a (possibly man-made) channel in the bedrock within the River Mersey to the entrance of the Brunswick Locks – this is shown in the form of levels and lines of dip on the Geo-Environmental Features Plan in Appendix 9, taken from maritime archives historic plans contained in Appendix 11.

Based on BGS boreholes and previous on-site boreholes, an indicative bedrock level contour plan has been produced. On this basis, it is anticipated that bedrock is shallower beneath the historic warehouse than in the area of the Brunswick Locks. However, this will need to be confirmed with intrusive site investigation. This contour plan is contained in Appendix 15.

Indicative bedrock levels are shown on the Indicative Cross Section Through Brunswick Quay in Appendix 10 and on cross sections and plans from the Maritime Archives and contained in Appendix 11.

Details of the recommended site investigation works are contained within Section 7.10.

Potential geotechnical hazards based on the expected ground conditions that may require further consideration at the site are outlined below:

Factors	Remarks	Considerations	Risk
Obstructions and Voids	Due to the site's varied development history and the significant infilling on site, there is a high likelihood of encountering many **significant obstructions**. It is known that in the construction of docks, high strength materials are used such as concrete with granite, and the Brunswick Dock walls are likely to be impervious. It is possible that the historic on site Graving Dock was left in-situ and infilled, or it could have been removed during the construction of the eastern site boundary (dock wall). Historic plans and cross sections included in Appendix 11 display contradicting information regarding the graving docks. If the Graving Dock remains in-situ, this will be a significant ground obstruction of high strength material. The infilled 100 Foot Lock has a concrete base up to 1.10m thick at circa 16m bgl. Many culverts and other conduits are also likely to be present cross cutting the site's sub-surface, along with various machine bases and lock features as noted on engineering plans contained within Appendix 11. It is possible that these have been infilled or removed or could remain in-situ as voids.	The noted obstructions may impede excavation works and / or the chosen foundation solution or act as 'hard spots' within the ground if left in-situ. Damage to a buried structure may create further hazards by instigating collapse or by releasing potential liquids or gases. Easements may be required for obstructions that are still in use (e.g. culverts / services). Voids may cause settlement issues and associated potentially significant movements can occur which can prove problematic for foundations, externals and highways. The presence of significant high strength obstructions will need to be taken into account during site investigation design and may limit the ultimate progress of works. A non-intrusive geophysical survey is recommended to detect the locations of obstructions and voids, although, it will not be exhaustive given the limits of the technique and the extensive nature of the anticipated obstructions / voids. If any of these features are unable to be found using non-intrusive methods, it may be necessary to probe piled foundation locations. Of particular importance is the location of the 1.52m diameter cast iron culvert which is anticipated to cross the south of the western site section and is located beneath the proposed building envelope at approximately 17.7m bgl, and the silt pumping pipe which is not noted on any known plans.	HIGH
Made Ground	Given the presence of the infilled 100 Foot Lock and possible infilling of the historic on-site graving dock, deep made ground is anticipated on-site. Previous site investigation at the site recorded significant thicknesses of made ground (up to 12.50m deep). The made ground may also be loose and / or voids may be present.	Made Ground may settle variably and may suffer significant movements / differential settlement due to causes other than imposed loading that may be problematic for foundations, externals and infrastructure elements.	HIGH
Alluvium	Previous site investigation at the site has recorded significant thicknesses of alluvium (up to 10.00m thick). This is likely to be very soft and organic.	Alluvium may cause consolidation issues, have poor bearing capacity and may suffer significant movements due to causes other than imposed loading that may be problematic for foundations. Any recovered alluvium deposits are unlikely to be suitable for any future re-engineering use without significant treatment.	HIGH
UXO	The Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment report for the site has designated the site at high risk of unexploded ordnance.	UXO from bombing raids during WWII may remain in the subsurface and all types of aggressive intrusive engineering activities, such as excavation works, piling and boreholes, have the potential to disturb and possibly activate UXO – follow the UXO	HIGH

		report recommendations for dealing with this risk when undertaking intrusive works at the site.	
Groundwater / Tidal Water	It is anticipated that the site groundwater will be subject to tidal influence and / or trapped perched water.	Given the anticipated tidal nature of the surface water together with the intrusive nature of the foundation solution e.g. piles, the subsurface water regime is likely to be dynamic and will require continuous monitoring to understand its potential influence on the proposed development.	MODERATE
Wall Stability	Brunswick Dock wall forms the eastern boundary and is not currently under significant loading as there are no on-site structures except a small electrical sub-station.	Construction of the proposed high rise development may cause increased surcharge to the dock wall. Consequently, an assessment of this should be undertaken along with the structural integrity of the wall. This is recommended to be taken into account in pile and externals design.	MODERATE
Variable Bedrock Level	As noted in Section 7.2 above, the bedrock level is suspected to vary in depth across the site. It is anticipated to be deeper in the western site section and shallower in the eastern site section.	Piled foundations may need to be advanced deeper in some areas of the site than others. Engineering design will need to account for this or any sudden interface between depths – intrusive site works are recommended to investigate the bedrock depth and properties.	MODERATE
Utility Infrastructure	Underground utility infrastructure may exist beneath the site as it has contained previous development and is located in a populous area.	Underground utility infrastructure, which may be live, may have easements, restricting access for subsurface investigations and other engineering works. Diverting such infrastructure can be costly and some such as main sewers cannot be diverted and instead impose development constraints.	MODERATE
Aggressive Ground and Groundwater	Given the anticipated depth of made ground (up to 12.50m bgl) and the unknown composition of the made ground, there is a potential for aggressive ground conditions to be present on-site. Also, the shallow groundwater beneath the site may be in continuity with brackish river / dock water.	Acidic ground / groundwater and sulphate may attack the existing and proposed concrete and steel used in foundations and react with aggregates. The oxidation of pyrite and other sulphides can also occur due to geotechnical activities. This can lead to the generation of high concentrations of sulphate and low pH that attacks construction materials and may lead to the precipitation of gypsum resulting in the heave of foundations and floor slabs. Pyrite oxidation can also be triggered by mixing susceptible materials with lime or cement resulting in high pH that can lead to the expansion of some sulphates that cause heave of stabilised soils. The high chloride content of brackish water also has the potential to attack buried steel.	MODERATE

7.3 Contaminated Land Legislative Framework

Environmental risks are assessed in accordance with Contaminated Land (England) (Amendment) Regulations (2012), Part IIA of the Environmental Protection Act 1990, and Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance, DEFRA (2012). Part IIA provides a statutory definition of contaminated land. To fall within this definition it is necessary that, as a result of the condition of the land, substances may be present on or under the land such that:

(a) Significant harm is being caused or there is a significant possibility of such harm being caused; or

(b) Significant pollution of controlled waters is being caused, or there is a significant possibility of such pollution being caused.

Risk from contamination is assessed by consideration of possible linkages between contaminant sources and potential receptors which could be harmed or polluted and the potential pathways between them – known as the Contaminant Linkage. For a risk of pollution or environmental harm to occur as a result of ground contamination, all of the following elements must be present:

- A source - a substance that is capable of causing pollution or harm;
- A receptor - something which could be adversely affected by the contaminant; and
- A pathway - a route by which the contaminant can reach the receptor.

If one of these elements is absent there can be no significant risk. If all are present then the magnitude of the risk is a function of the magnitude and mobility of the source, the sensitivity of the receptor and the nature of the migration pathway.

The Environment Agency Contaminated Land Report CLR 11 Model Procedures for the Management of Land Contamination provides the technical framework for structured decision making about land contaminations. CLR 11 advocates a phased approach to risk assessment comprising:

- Preliminary Risk Assessment (PRA) - desk study and qualitative assessment;
- Generic Quantitative Risk Assessment (GQRA) - assessment of contaminant concentrations against generic assessment criteria; and

- Detailed Quantitative Risk Assessment (DQRA) - detailed site specific risk assessment and development of site-specific assessment criteria.

Each of these phases follows the same basic steps but adds site specific details and further certainty into the assessment as the stages progress. The basic steps are:

- Hazard Identification and hazard assessment- development or refinement of the source-pathway-receptor conceptual model, and identification of potential pollutant linkages;
- Risk Estimation- qualitative risk estimation predicting magnitude and probability of potential consequences that may arise as a result of a hazard; and
- Risk Evaluation- deciding whether a risk is unacceptable.

The key to the classification is that the designation of risk is based upon the consideration of both:

(a) the magnitude of the potential consequence (i.e. severity) [takes into account both the potential severity of the hazard and the sensitivity of the receptor]; and
(b) the magnitude of probability (i.e. likelihood) [takes into account both the presence of the hazard and receptor and the integrity of the pathway].

Generic Quantitative Risk Assessment (GQRA) will utilise generic assessment criteria (GAC) for the purposes of screening allowable concentrations in comparison to the measured site concentrations. The GAC are defined based on the critical receptors identified at the site. Receptors are considered in relation to:

- Human health receptors (e.g. site users) via measured solid concentrations; and
- The water environment (e.g. groundwater and surface water) via measured leachate / water concentrations.

Additional receptors may be relevant dependant on the site eg flora/fauna, water supply pipes, buried concrete.

The GAC adopted for assessment of soils in relation to Human Health are based on published Soil Guideline Values (SGV) in 2009 for those compounds for which published criteria are available for varying scenarios (residential, commercial, allotment). In the absence of SGVs the following GAC defining documents are adopted - LQM/CIEH S4ULs (2015), CL:AIRE Soil GAC for Human Health Assessment (2010) and Category 4 Screening Levels (C4SL's) (2014).

GACs for waters must be selected to assess potential risks to the identified environmental receptors. There are numerous UK and European guidelines for waters based on the site situation and different receptors. GACs utilised include - The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2009 (Part 7:Groundwater Threshold Values), UK Drinking Water Standards (2000), Environmental Quality Standards, World Health Organisation concentrations, Environment Agency guidance concentrations and United States Environmental Protection Agency – Region 9 GACs.

7.4 Sources of Contamination and Probable Contaminants

On the basis of the reviewed information the following potential contaminative sources have been identified:

Source ID	Potential Contaminative Activity and Date	Associated Determinands	Comments
1	On and off site dockyards and dockland (1837 earliest available mapping to present)	**Suite 1** – detailed below. Timber preservatives.	Wide range of determinands possible due to industrial area. Timber-related contaminants including preservatives such as creosote possible as Brunswick Dock was originally constructed for timber import.
2	Infilling of Brunswick 100 Foot Lock and graving Docks including natural organic alluvium left in-situ (approx. 1984)	**Suite 1** – detailed below. Ground gases.	Made ground fill could contain a wide range of determinands including asbestos.
3	On and off-site ship building industry (mid 1800s to early 1900s)	Metals, fuels, oils, organic compounds including paints and solvents, acids, cyanides, asbestos, VOCs.	Contaminants likely to be found in infilled on-site Graving Dock (see 2 above).
4	Possible contaminated silt	Ground gases. Microbiological contamination (i.e. Anthrax).	Unknown if still present but possible within infilled 100 Foot Lock.
5	On-site electrical sub-station	PCBs	Risk is dependent on age and condition of sub-station.
6	Off-site railway	Heavy metals, oils, ash.	-

Suite 1: pH, Sulphate (2:1 Water Soluble) as SO_4, Sulphur, Sulphide, Boron (Hot Water Soluble), Cyanide (Free), Cyanide (Total), Arsenic, Barium, Chromium, Zinc, Cadmium, Copper, Nickel, Lead, Mercury, Beryllium, Vanadium, Selenium, Chromium (Hexavalent), Organic Matter, Total Petroleum Hydrocarbon screen followed by Speciated Aliphatic and Aromatic Total Petroleum Hydrocarbon Fractions (TPHCWG) where applicable and Speciated Poly Aromatic Hydrocarbons (PAHs).

PCBs will be tested where applicable in areas surrounding the on-site electrical sub-station.

In areas of anticipates asbestos risk, made ground solid samples selected for chemical testing will also be tested for asbestos. Positive asbestos identification will be quantified for further analysis.

7.5 Conceptual Model for Human Health Risk Assessment

On the basis of the above specified Potential Contaminative Activities and the associated determinands, a conceptual model in the form of a linkage table for the purposes of a preliminary risk assessment for human health receptors from these determinands has been established:

Determinands	Pathway	Receptor	Comment	Risk
Metals Semi-metals Inorganics TPH PAHs PCBs	Ingestion of contaminated soil and dust (indoor and outdoor) Dermal contact with contaminated soil (indoor and outdoor) Inhalation of contaminated dust (indoor and outdoor)	End-user	Made ground is anticipated to underlie the entire site in varying thickness and content, possibly in a significant thickness in places as identified in previous site investigation. A wide range of potentially harmful determinands are anticipated. However, the proposed development will reduce any risk to human health due to the proposed 100% hardstanding cover.	**VERY LOW**
		Construction worker General public	Made ground is anticipated to underlie the entire site in a significant thickness as identified in previous site investigation. A wide range of potentially harmful determinands are anticipated. Possibility for contaminants to have accumulated within conduits cross-cutting the site. Construction workers will be at the highest risk due to direct contact, and the general public are at risk of inhalation of contaminated dust. However, previous SI did not find significant contamination harmful to human health.	**LOW**
Volatile fraction of above contaminants i.e. semi volatile PAHs and hydrocarbon vapours	Inhalation of soil vapours (indoor and outdoor)	End-user Construction worker General public	A source of these contaminants has been identified but is not anticipated to be widespread. Potential risk to end users due to ingress and accumulation within the proposed development. Potential risk to construction workers from spontaneous release or accumulation within small temporary rooms. Negligible risk to general public	**LOW**
Asbestos	Inhalation of airborne fibres	End-user	Due to the age of the historic on-site buildings, they are likely to have contained asbestos. Also, previous boreholes have found that the 100 Foot Lock has been infilled with demolition waste, which at the time of filling is highly likely to contain asbestos. The end user is at a reduced risk due to the absence of pathways as the site is proposed to be covered entirely in hardstanding. The risk of contact is very low.	**VERY LOW**
		Construction worker General public	Due to the age of the historic on-site buildings, they are likely to have contained asbestos. Also, previous boreholes have found that the 100 Foot Lock has been infilled with demolition waste, which at the time of filling is highly likely to contain asbestos. The construction worker is at the highest risk due to direct contact and direct inhalation. The construction process may yield airborne fibres, putting the general public at risk.	**HIGH**
pH Sulphate Sulphur Sulphide	Direct contact with building fabric and chemical attack on concrete	Building structure and fabric of buildings on and off site	Acids are likely to have been used in historic ship building industry and may remain in the sub-surface. Previous Geotechnics Ltd. SI has found elevated total sulphur, total sulphate and sulphide; Design Sulphate Class of DS-2 and ACEC Class of AC-2.	**MODERATE**
Microbiological (i.e. Anthrax)	Ingestion of contaminated soil and dust (indoor and outdoor) Dermal contact with contaminated soil (indoor and outdoor) Inhalation of contaminated dust (indoor and outdoor)	Construction worker	Hazard is high due to possibility of harmful disease can be caused by a single spore, however likelihood of *Bacillus anthracis* remaining in silt after c. 40 years is low.	**MODERATE**

7.6 Conceptual Model for Ground Gas Risk Assessment

On the basis of the above specified Potential Contaminative Activities, a conceptual model in the form of a linkage table for the purposes of a preliminary risk assessment for ground gas has been established:

Source	Ground Gas	Pathways	Receptors	Comment	Risk
Organic alluvium	Methane Carbon Dioxide Hydrogen Sulphide	Migration, ingress and accumulation Inhalation	Human occupants Building and Structures Site Workers	Highly likely. Previous SI included monitoring of a well installed directly in the organic rich alluvium deposits in the area of the historic on-site warehouse and found up to 88.6% v/v methane and >99.9l/hr flow. Possible that this source is isolated and can be vented as suggested by Geotechnics Ltd. but this is unknown without further site investigation.	**HIGH**
Made ground				Other made ground on site is unlikely to be a ground gas source. However, isolated organic pockets may be present but ground gas generation is anticipated to be low.	**LOW**

7.7 Conceptual Model For Controlled Waters Risk Assessment

As there are no recorded superficial deposits on site, it is considered that there is no superficial aquifer present on site.

An off-site borehole found potential aquifer groundwater within the sandstone bedrock at 13.70m bgl. However, the on-site BGS boreholes and the previous on-site Geotechnics Ltd. investigation did not record aquifer groundwater, despite being drilled to a maximum depth of approximately 40m bgl. Therefore, there is uncertainty regarding the presence / depth of the Principal Aquifer underlying the site.

The previous on-site SI encountered groundwater within the infilled 100 Foot Lock between 3.0m and 4.0m bgl. This was at the same level as the water within Brunswick Dock and is potentially in hydraulic continuity with the dock. Therefore, this is 'surface water'.

The previous on-site SI also encountered groundwater in the area of the previous on-site large building at a depth of approximately 7.0m bgl. This was at the same level as the adjacent River Mersey and is considered to be in hydraulic continuity with the underground river flow. Therefore, this is also 'surface water'.

In addition to this, the site is likely to contain many culverts and other conduits which will connect the dock to the river, and possibly act as channels for washing out of contaminants or as areas for contaminants to accumulate.

On the basis of these identified groundwater regimes, and on the basis of the above specified Potential Contaminative Activities and the associated determinands, a conceptual model in the form of a linkage table for the purposes of a preliminary risk assessment for controlled waters receptors from these determinands has been established:

Sources of Contamination	Pathway	Receptor	Comment	Risk
Metals Semi-metals Inorganics TPH PAHs PCBs pH Sulphate	Migration through ground vertically into aquifer groundwater	Principal Aquifer Discharges from groundwater, e.g. springs and rivers	Although aquifer groundwater has not been encountered on site, there remains the possibility that it can be found deeper than has been explored. This is a highly sensitive receptor. Possibility of mobile contaminants migrating downwards to the aquifer, however, water enters from the adjacent dock and river, so it is likely that most of the mobile contaminants have been washed out. Also, the proposed 100% hardstanding of the proposed development and the increase in drainage will reduce infiltration.	**LOW**
	Overland flow Migration through ground laterally	Surface water courses – Brunswick Dock and the River Mersey Aquatic organisms	Surface water from Brunswick Dock potentially enters the western site section and surface water from the River Mersey potentially enters the eastern site section. This will effectively wash out mobile contaminants. This will have been occurring for a significant time and it is unlikely that any contaminants but the most refractory will remain. Also, significant dilution will occur within Brunswick Dock and within the River Mersey. The proposed development will increase hardstanding and drainage and therefore decrease infiltration and runoff.	**LOW**

7.8 Preliminary Risk Assessment Summary

Human Health

On the basis of the site's varied development history, numerous contaminative sources have been identified. On the basis of the human heath conceptual model, a very low to low risk to end-users, construction workers and the general public has been identified from chemical contaminants and their volatile fractions. The risk of asbestos has been assessed as very low to the end user and high to construction workers and the general public. However, this can be mitigated with appropriate PPE and dust suppression measures. A moderate risk to construction workers has been identified with respect to anthrax and acidic ground conditions. Control measures are recommended to be emplaced during intrusive investigation and construction works to safely and effectively reduce these risks.

Ground Gas

On the basis of previous on-site investigation finding a methane concentration of >80% v/v and an associated flow above detection limits, it is anticipated that the alluvial deposits within the eastern site section (and possibly elsewhere on site) are a high generation gas source – therefore a high risk has been assigned. Other made ground on site has been assigned a low risk as it is anticipated mostly to be a low generation source.

Controlled Waters

There is no superficial aquifer on site. The depth of the Principal Aquifer within the sandstone bedrock on-site is unknown, however, this is still a highly sensitive receptor. The shallow groundwater encountered on site is considered to be in hydraulic continuity with the surrounding surface water. The conceptual site model has identified a low risk to these receptors.

Summary

As a result of the risks and uncertainties identified, a Phase 2 intrusive ground investigation including contamination testing of soils and groundwater and ground gas monitoring should be undertaken on the basis of the findings of this Phase 1

report. Also, suitability testing should be undertaken for the on-site re-use or off-site removal of soils won from the site.

Depending on the levels of contaminants encountered on site, a Phase 3 numerical risk assessment may be required to determine the acceptable levels of contamination.

It should be noted that appropriate chemical testing will be required in order to appraise the suitability for the sub-surface potable plastic water pipe – dependent on the requirements of the responsible service provider further site intrusive works may be required.

A diagrammatic site conceptual model for the purposes of a preliminary risk assessment for human health, ground gas and controlled waters has been produced as a result of the probable contaminants, pathways and targets identified in Section 7.5 above, and is included in Appendix 12.

7.9 Scope of Phase 2 Intrusive Geo-Environmental Ground Investigation

As a result of the preliminary risk assessment, a Phase 2 intrusive environmental ground investigation should be carried out to quantify the identified risks and to determine the geotechnical and geological properties of the underlying ground conditions. The rationale and aims for these Phase 2 environmental, geotechnical and geological investigative works are detailed below. Given the complex nature of the site the proposed site investigation works are proposed on a staged basis as noted below:

7.9.1 Stage 1

Geophysical Exploratory Works Rationale

Due to identified high potential for significant obstructions within the site subsurface, it is considered prudent to undertake a non-intrusive survey to identify the location, size and depth of any of these features, including obstructions, conduits, services and voids.

Many of the obstructions / voids likely to be encountered are identified on the Geo-Environmental Site Features Plan contained in Appendix 9.

7.9.2 Stage 2

During the following recommended Stage 2 site investigation, it is important to investigate and account for the possible microbiological hazard. As explained above in Section 6.10, a residual risk of anthrax contaminated silt remains beneath the site.

It is recommended that the risk of anthrax at the site is determined by microbiological laboratory testing and that the risk to on-site personnel during intrusive works is minimised by employing the following protective measures:

When undertaking intrusive site works, the Health and Safety Executive (HSE) recommends that preventative measures are emplaced including, but not limited to:

- wearing disposable coveralls and gloves;
- following good basic hygiene including regular hand-washing and avoiding hand to mouth/eye etc contact;
- taking rest breaks, including meals and drinks, away from the work area, and;
- covering all cuts, abrasions and other breaks in the skin with waterproof dressings and/or gloves.

Respiratory Protective Equipment (RPE) with an assigned protection factor of 20, and immunisations are also suggested when the risk is high. However, based on the information contained within Section 6.10 above, the requirement for RPE and / or immunisations are not anticipated. Nevertheless, contingency measures will be emplaced in the event that animal hair be identified, following ceasing of all works until the risks are controlled.

The site has been designated a high risk of UXO by Alpha 6 and measures during site investigation will be required – as detailed within the Alpha 6 Report contained within Appendix 14.

Geotechnical and Geological Exploratory Hole Rationale

It is proposed to undertake exploratory holes to:

- facilitate the logging and sampling of made ground and superficial strata for geotechnical laboratory testing
- facilitate in-situ geotechnical testing e.g. SPTs
- locate and determine the depth / thickness of sub-surface obstructions e.g. graving dock, 1.52m diameter cast iron culvert, etc, anomalies, soft spots and voids.
- undertake chemical testing of solid samples for soluble sulphate (2:1 extract) and / or total sulphate and pH to determine the suitable concrete classification in associated with relevant guidance e.g. BRE Special Digest 1
- undertake chemical testing of groundwater samples to determine whether it is brackish – if so, the chloride content may have implications for the attack of buried steel
- determine the depth to the underlying sandstone bedrock. It is anticipated that the bedrock is deeper in the western site section and shallower in the eastern site section;
- determine the geological properties of the of the underlying sandstone e.g. FI, TCR, SCR and RQD;
- Within the proposed extent of post–development hard landscaping, it is recommended that in-situ CBR tests are undertaken in order to determine the required external works design parameters.

<u>Environmental (contaminated land) Exploratory Hole Rationale</u>

Based on the Preliminary Risk Assessment, it has been identified that the risk to the end user is low due to the proposed 100% hardstanding on site. However, construction workers will be at a much higher risk due to direct contact together with allowing for classification of materials for re-use / disposal. It is therefore proposed to undertake exploratory holes to:

- facilitate the logging and sampling of strata for chemical laboratory testing;
- determine the presence of visual and olfactory evidence of contamination;
- determine the presence of conduits possibly containing pooled contamination;
- collect appropriate samples – solid, ground gas and liquid across the site for appropriate chemical testing as detailed in Section 7.4;

- facilitate the installation of wells for the purposes of gas and groundwater monitoring and sampling;
- undertake continuous ground gas concentration and flow monitoring across site to determine the ground gas regime for at least 3 weeks with spot monitoring visits to follow;
- undertake purge / flux tests of the ground gas wells;
- install dataloggers in monitoring wells to determine the tidal nature of the groundwater and correlate with ground gas monitoring data to determine the effect of variable groundwater levels on the ground gas regime – this has geotechnical implications also.

Methods for the above proposed investigation are to be agreed based on commercial factors, site constraints and the results of the proposed non-intrusive survey. However, the investigation techniques are likely to include trial pits, shell and auger boreholes, CPT rigs, sonic percussive holes and rotary core recovery holes.

Exploratory holes will be undertaken on both a targeted and spatial basis to allow a representative view of the subsurface to be obtained. The chemical testing will be undertaken in line with the identified chemical suites noted in Section 7.4.

Additionally, it has been identified that significant material management is likely to be undertaken on the site. This may involve the removal of sub-surface features / obstructions and the removal of significant quantities of pile arisings if a CFA solution is adopted. Therefore, geotechnical testing will determine the potential reusability of materials and chemical laboratory testing will determine their waste classification or on-site reusability.

8.0 RECOMMENDATIONS

8.1 As a result of the risks identified, a Phase 2 intrusive environmental ground investigation including contamination testing of soils and groundwater together with ground gas monitoring and assessment should be undertaken based on this Phase 1 report. Due to geotechnical requirements, site investigation works should also be undertaken to determine the ground conditions with more certainty and allow design of the proposed development – foundations, ground floor slabs, drainage, external etc, as detailed above in Section 7.9.

8.2 The site has been designated a high risk of UXO by Alpha 6 and measures during site investigation, groundworks and piling works will be required – as detailed within the Alpha 6 Report contained within Appendix 14.

8.3 From the results of the Phase 2 site investigation work – if this report identifies a potential risk and / or a requirement for further detailed site-specific assessment, a Phase 3 environmental investigation report including a and / or a Remedial Strategy (informing on potential remediation solutions) may be required.

8.4 The nature and extent of the proposed targeted chemical and environmental testing should be confirmed, if time / commercial constraints, allow with the relevant Local Authority Environmental Health Officer and the Environment Agency prior to undertaking works on site. Proceeding without agreement between regulatory authorities may result in further assessment being required.

8.5 It should be noted that, if any visual or olfactory evidence of contamination is encountered during remediation or construction work, then the Local Authority Environmental Health Officer and Environment Agency should be contacted immediately in order to agree any necessary remediation measures.